CLOUDS AND THE EARTH'S RADIANT ENERGY SYSTEM (CERES)

CERES VALIDATION PLAN

ERBE-LIKE AVERAGING TO MONTHLY TOA FLUXES (SUBSYSTEM 3.0)

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Release 2.2
July 1997

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3.1 INTRODUCTION

3.1.1 Measurement and science objectives

A major emphasis of radiation budget research is on the monitoring and analysis of long-term variations in the Earth climate system. This can only be accomplished using stable, long-term global data sets. The chief science objective of the CERES Subsystem 3 is to fulfill this research need. Specifically, this subsystem will provide averages of top-of-atmosphere (TOA) and surface radiative parameters from CERES scanner measurements of shortwave (SW) and longwave (LW) flux using a data processing system consistent with the earlier Earth Radiation Budget Experiment (ERBE).

3.1.2 Missions

The CERES instruments will be flown on multiple satellites, which include TRMM, EOS AM-1, and EOS PM-1, to provide the diurnal sampling necessary to obtain accurate monthly averages of the TOA radiative parameters.

3.1.3 Science data products

The CERES ERBE-like processing algorithm produces three different science products. They are ERBE-like Science Product 4 (ES-4), ERBE-like Science Product 4 Gridded (ES-4G), and ERBE-Like Science Product 9 (ES-9). Each of the science products contains temporally and spatially averaged CERES scanner estimates of the upward SW and LW flux at the TOA. The ES-4 and ES-4G are regional (i.e., 2.5 degree, 2.5 degree nested to 5.0 degree, and 5.0 degree nested to 10.0 degree), zonal (such as 2.5, 5.0, and 10.0 degree), and global average products arranged temporally to days, monthly-hours, and the month. Furthermore, ES-4 and ES-4G are identical products except in arrangement of the data. While the ES-4 science product is arranged by region, the ES-4G file presents a gridded data product with all regions for a given data parameter grouped together. The ES-9 is a product of regional (2.5 degree) average only. The data in the ES-9 product are stored by the hour for each hour of each day in the month. There are 77, 74, and 243 data parameters in the ES-4, ES-4G and ES-9 science products, respectively. These include the mean estimates of SW and LW radiant flux at the TOA, the standard deviations of these estimates, the maximum and minimum estimate, and scene information or cloud condition. The complete list of these data parameters can be found in the CERES Data Products Catalog.

In the next section, we will outline the method adopted by the CERES Time Interpolation and

Spatial Averaging (TISA) working group for validating these ERBE-like data parameters. Section 3.3 will concentrate on pre-launch validation. The post-launch activities will be described in section 3.4. Section 3.5 will discuss the implementation of the validation data set in data production. A final summary is given in section 3.6.

3.2 VALIDATION CRITERION

3.2.1 Overall approach

The ERBE-like data processing system algorithm is very similar to those used by ERBE. Specifically, it uses a comprehensive set of LW and SW angular dependence models to convert radiances to fluxes. In addition, special averaging procedures are used to produce monthly mean of TOA radiative parameters on various spatial and temporal scales. Details of this science algorithm can be found in the CERES ATBD document. The inputs into this subsystem include CERES scanner observation of SW and LW TOA flux, satellites viewing geometry, latitude and longitude of the measurement, the underlying geographic scene type, cloud amount information, TOA albedo angular distribution models (ADMs), and solar declination. The outputs of this subsystem are daily, monthly-hourly, and monthly means of TOA SW and LW flux on regional, zonal, and global scales.

The validation of the ERBE-like subsystem is an integral part of the CERES system. The purpose of this validation is to thoroughly test the subsystem and detect possible problems or errors. This activity includes the validation of both the ERBE-like science algorithms and the ERBE-like science data product. The ERBE-like science algorithms are declared to be completed and validation activities will cease if the following criteria for the science algorithms are satisfied:

(a) The technique in the science algorithms is finalized (i.e., completing pre-launch science studies).
(b) The accuracy criteria of the science algorithm are met.
(c) The data processing system is completed (i.e., verifying input/output operations and interface compatibility with other subsystems).
(d) No reprocessing of the science data product is recommended.

If these criteria are not met, the validation of the science algorithm will continue. The validation criteria for the science data product are similar to those given by the science algorithm. Specifically, the science data product is declared to be valid if the following two criteria are met:

(a) The science data product can be verified from independent data sources of known precision and/or accuracy.
(b) The science data product does not violate known physical principles.

Unlike the science algorithms, this validation activity will not stop after the initial verification of

the data product. On the contrary, validation of the ERBE-like data product will continue as long as input data is available. This activity is necessary in order to maintain continuous monitoring of the quality of the input data product and to detect problems/errors in the overall system.

In order to conserve resources, the CERES TISA working group will not be validating every single data parameter listed in each of the ERBE-like science products. Instead, the TISA working group will concentrate on a few of the most important data parameters. These parameters include (a) the LW and SW TOA total-sky flux and (b) the LW and SW TOA clear-sky flux.

3.2.2 Sampling requirements

In order to validate ERBE-like data products, we will require a minimum of one year of data from each of the CERES satellites. Additional data months are also required to perform data consistence test between different satellites (i.e., TRMM against AM, TRMM against PM, and AM against PM).

3.2.3 Measures of success

Several studies of the ERBE error sources (i.e., Harrison et al., 1990) have resulted in reliable estimates of the uncertainties in monthly mean TOA LW and SW radiation. The results of these studies are outline in table 1. Estimates are made for clear-sky and all-sky conditions. This table will serve as the best estimates of the accuracy goal currently achievable by the ERBE-like subsystem. However, these accuracy values will be updated by the TISA working group as more information becomes available. Overall, the CERES TISA working group expected the errors in the monthly mean TOA radiative parameters to be small. Bias errors for regional all-sky fluxes are less than 1 Watts/m^2. The rms uncertainties in all-sky LW and SW fluxes are estimated to be 3 and 5 Watts/m^2, respectively. The rms errors in clear-sky LW and SW fluxes are estimated to be 2 Watts/m^2. The clear-sky LW and SW fluxes, however, is overestimated by about 4 and 1 Watts/m^2, respectively.

In order to approach the validation activity in a systematic matter, the CERES science team has adopted a two-steps process for validating this subsystem. This process can be broken down into the pre-launch and the post-launch validation. The details of these validations are outlined in the next two sections.

3.3 PRE-LAUNCH ALGORITHM TEST/DEVELOPMENT ACTIVITIES

3.3.1 Field experiments and studies

N/A

3.3.2 Operational surface networks

N/A

3.3.3 Existing satellite data

The objective of the pre-launch activities is to validate the methods and algorithms used in the production of ERBE-like science data product. The CERES's TISA working group has implemented the following procedures for pre-launch testing of the ERBE-like science algorithm:

(a) All required input data for the subsystem are collected.
(b) Science algorithm of the subsystem is used to process the input data.
(c) Output data from the subsystem are verified against known results.
(d) Retesting of the improved science algorithms is required if the original science algorithms fail during the processing stage or the final outputs fail to verify against known results.

Since large portions of the ERBE-like data processing software are based on the successful ERBE method, the pre-launch algorithm testing of this subsystem are based mostly on inputs from existing ERBE TOA scanner data set. Field experiments, field studies, and operational surface networks are not required as inputs for testing this subsystem at the current time. Using these existing ERBE TOA scanner data, TISA working group has already completed most of the prelaunch science testing of the ERBE-like algorithms. The results of these activities are reported in the CERES ATBDs. Additional tests based on CERES system-wide end-to-end pre-launch simulation of Release 1 algorithm with October, 1986 data set have been scheduled for this summer. During the data processing stage of this testing period, a careful analysis will be done to access the robustness of the data algorithm in handling data ingest and output production operations. Questions concerning software and system-wide problems will be addressed. In addition, the data processing system will be tested for interface compatibility with other CERES subsystem. Timing tests will be performed to define future scheduling requirements.

The verification of the ERBE-like TOA results produced by the science algorithms requires the use of an independent data set. A set of intercomparison studies between the ERBE-like results and the known ERBE results has be carried out. Results of these studies are reported in the CERES ATBDs. Additional tests based on the end-to-end simulation will be performed sometime this summer. During this testing stage, a special validation output product will be produced. This product will contain the following items:

(a) Time series plots of radiation parameters over a pre-selected set of validation regions, latitude zone, and the globe.
(b) Zonal and global averaged monthly mean images of these parameters.
(c) Two dimensional error analyses results of the data product (if available).

A list of the pre-selected validation regions with their latitude and longitude values is outlined in Table 2. These regions which cover a wide range of climatic regions will be useful in testing the overall robustness of the ERBE-like algorithm in handling data for various scene types and cloudiness conditions. The special validation output product will be used to identify and to record problematic areas associated with the ERBE-like data product.

Finally, the last stage of the pre-launch algorithm testing involves algorithm development activities. The purpose of this stage is to correct any systematic problems that have been encountered during the pre-launch testing period. Improved science algorithms will be developed. Retesting and redevelopment of the science algorithms will continue until all the problems have been resolved and the output products verified against known results.

3.4 POST-LAUNCH ACTIVITIES

3.4.1 Planned field activities and studies

N/A

3.4.2 New EOS-targeted coordinated field campaigns

N/A

3.4.3 Needs for other satellite data

The post-launch validation will concentrate on examination and verification of the ERBE-like results. Specifically, the main purpose of these activities is to determine whether the ERBE-like results are qualitatively acceptable and agree reasonably well with expected quantitative results derived from other independent data sources. The CERES TISA working group has tentatively adopted the following procedures for the post-launch validation activities of the ERBE-like data products:

(a) CERES TOA scanner data sets are collected during intensive initial validation period as input into the data processing system.
(b) Independent data sets that match the initial validation period are collected for intercomparision studies.
(c) Intensive initial validation of the output data against the independent data sets is performed to ensure accuracy of the output results.
(d) Continuous quality control of the input data sets and constant monitoring of the output data will be implemented after the intensive initial validation period to detect problems/ errors in the overall system.

The intensive initial validation is tentatively scheduled after the ingestion of each of the following data sets and the completion of their corresponding validation data;

(a) first full month of CERES scanner data.
(b) first full season of CERES scanner data.
(c) first full year of CERES scanner data.

Three separate sets of these validation activities, corresponding to each of the CERES satellite

data sets (i.e., TRMM, EOS-AM, and EOS-PM), will be executed.

During the intensive initial validation, a thorough error analysis and time series studies will be performed to access the quality of the new ERBE-like data set. A special validation output similar to that outlined for the pre-launch validation will be produced to aid the validation activities. A number of independent data sets will be needed for the intensive validation of the ERBE-like TOA product. Specifically, the CERES TISA working group plans to use 1-hourly (if available) and 3-hourly geostationary data (i.e., GOES-8, GOES-9, METEOSAT, and GMS) as the primary source of validation data set. In order to facilitate intercomparison between the two data sets, the narrowband radiances on the geostationary satellites will be converted to broadband fluxes using narrowband-to-broadband conversion relationships. In addition, TISA working group will also be acquiring data, if available, from ERBE, ScaRaB, and the new European Geostationary Earth Radiation Budget (GERB) for direct TOA flux intercomparision.

After the intensive initial validation is completed, the CERES TISA working group plans to continue monitoring the quality of the input data set and to correct any problems associated with the overall ERBE-like subsystem. Special validation output products will be used extensively during this period. This activity will continue as long as input data are made available to this subsystem.

3.4.4 Measurement needs (in situ) at calibration/validation sites

N/A

3.4.5 Needs for instrument development

N/A

3.4.6 Geometric registration site

N/A

3.4.7 Intercomparisons

After the launch of the EOS AM-1 and the EOS PM-1 satellite, the new CERES radiation data set can also be validated by comparison with special validation data products from the TRMM satellite. EOS PM-1 can also be compared with EOS AM-1 data.

3.5 IMPLEMENTATION OF VALIDATION RESULTS IN DATA PRODUCTION

3.5.1 Approach

The procedures for pre-launch and post-launch validation of this subsystem have been outlined in the previous section. The results of these validations should, in general, lead to further improvement in the quality of the CERES data set. Major problems discovered after data produc-

tion will be recorded and techniques for resolving them will be developed. The new algorithms will remain consistent with ERBE. The correction of these problems will then be implemented during the CERES data reprocessing period.

3.5.2 Role of EOSDIS

EOSDIS will provide special processing of CERES ERBE-like data products for regions containing validation sites.

3.5.3 Plans for archival of validation data

The results of the validation and their associated problems will be stored at the NASA Langley Research Center. The user community can access this information either through an anonymous FTP account or through the use of World Wide Web browser technology.

3.6 SUMMARY

This document describes a plan for validating the CERES ERBE-like data products. The validation plan is broken up into two stages; the pre-launch and the post-launch stage. Minimum of one year of data from each of the CERES satellites will be required to validate the data products. The validation efforts will be concentrated on a set of emphasized parameters. A set of special validation regions will be used to identify and to record problematic areas associated with the ERBE-like data product. EOSDIS will provide special processing of CERES ERBE-like data products for regions containing these validation sites.

Many of pre-launch activities have been completed to verify the ERBE-like algorithm using existing ERBE TOA scanner data. The results of these activities are reported in the CERES ATBDs. Additional pre-launch tests based on CERES system-wide end-to-end simulation are being scheduled in the summer. The post-launch validation will concentrate on using geostationary data to verify the ERBE-like data products. Secondary data sets, if available, will be obtained from ERBE, ScaRaB, and GERB for direct comparison. In addition, data obtained from different CERES satellites can be used to validate each other. The results of the validation and their associated problems will be stored at the NASA Langley Research Center. The user community can access this information either through an anonymous FTP account or through the use of World Wide Web browser technology.

REFERENCE

Harrison, E. F., P. Minnis, B. R. Barkstrom, V. Ramanathan, R. D. Cess, and G. G. Gibson, 1990: Seasonal variation of cloud radiative forcing derived from the Earth Radiation Budget Experiment. *J. Geophys. Res.*, **95**, 18687-18703.

Table 1: Accuracy Estimates for Monthly Mean Regional Product (Watts/m^2).

Parameter	Clear-sky Bias Error	Clear-sky RMS Error	All-sky Bias Error	All-sky RMS Error
TOA SW_{up}	1	2	< 1	5
TOA LW_{up}	4	2	< 1	3

Table 2: Special CERES's TISA Validation Regions.

Region	Type	Location	Lat	Lon	Region	Type	Location	Lat	Lon
1	Ocean	N. Alantic (ASTEX)	37.5N	22.5W	16	Desert	Sahel	14.5N	0.5E
2	Ocean	Atlantic Gulfstream	38.5N	71.5W	17	Desert	S. Africa Desert	22.5S	21.5E
3	Ocean	Trop. Atlantic	4.5N	24.5W	18	Desert	Gibson Desert	27.5S	124.5E
4	Ocean	SE. Altanic	10.5S	9.5E	19	Land	Europe	47.5N	2.5E
5	Ocean	Pacific/FIRE stratocumulus	33.5N	122.5W	20	Land	NW. U.S.	44.5N	119.5W
6	Ocean	W. Pacific	33.5N	142.5E	21	Land	W. U. S.	44.5N	109.5W
7	Ocean	Trop. Pacific	0.5N	134.5W	22	Land	ARM/ Oklahoma site	36.5N	97.5W
8	Ocean	E. Pacific	4.5N	84.5W	23	Land	Tibet	33.5N	89.5E
9	Ocean	ARM/Trop. W. Pac. TOGA/CORE	0.5S	155.5E	24	Land	Middle East	32.5N	57.5E
10	Ocean	Trop. E. Pacific	22.5S	75.5W	25	Land	N. India	24.5N	75.5E
11	Ocean	Midlat. S. Pacific	50.5S	140.5W	26	Land	Borneo	0.5N	113.5E
12	Ocean	Indian Ocean	5.5N	65.5E	27	Land	S. Amer/ trop highlands	2.5N	62.5W
13	Desert	SW. U.S.	33.5N	114.5W	28	Land	Amazon Basin	2.5S	62.5W
14	Desert	E. Sahara	24.5N	20.5E	29	Land	E. Brazil	5.5S	44.5W
15	Desert	Saudi Desert	21.5N	45.5E	30	Land	S. Africa	14.5S	20.5E

CERES VALIDATION PLAN

3.0 ERBE-LIKE AVERAGING TO MONTHLY TOA FLUXES

DATA PRODUCTS/PARAMETERS

- ERBE-like clear-sky and all-sky radiative parameters at the TOA on various spatial (regional, zonal, and global) and temporal (daily, monthly-hourly, and monthly mean) scales.

MISSIONS

- TRMM, EOS AM-1, and EOS PM-1

APPROACH

- Complete pre-launch science studies for improving and verifying TISA methods.
- Verify input/output operations and interface compatibility with other subsystems.
- Compare ERBE-like results with validation data sets.

PRELAUNCH

- Complete validation of the ERBE-like science algorithm.
- Finish testing of the ERBE-like data processing system.
- Verify ERBE-like TOA results with existing ERBE scanner data.
- Validate data processing system using CERES end-to-end simulation.

POST-LAUNCH

- Primary comparison with geostationary data using narrowband-to-broadband conver-

sion technique.

- Secondary direct verification (if available) with ERBE WFOV results, ScaRaB data, and GERB data.
- Additional intercomparison between TRMM, EOS AM-1, and EOS PM-1 data.
- Continuous monitoring of the quality of the input data product and detecting problems in the overall system.

EOSDIS

- Special processing of CERES ERBE-like data products containing validation sites.